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This handbook for the port of Haifa, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

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SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

15. HAIFA

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CONTENTS

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (CNOC) requirements validated by the Chief of Naval Operations (CNO).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to NOCC, Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

M. G. SALINAS
Commander, U.S. Navy

ACKNOWLEDGMENT

The authors gratefully acknowledge the contributions made to development of port evaluations for Ashdod and Haifa by the Coastal and Marine Engineering Research Institute, Technion City, Haifa, Israel. The published evaluations make extensive use of the Institute's studies of these ports as sources of information and operational guidance.

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT
1	GAETA, ITALY
2	NAPLES, ITALY
3	CATANIA, ITALY
4	AUGUSTA BAY, ITALY
5	CAGLIARI, ITALY
6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
	BARCELONA, SPAIN
	PALMA, SPAIN
	IBIZA, SPAIN
	POLLENSA BAY, SPAIN
	VALENCIA, SPAIN
	CARTAGENA, SPAIN
	GENOA, ITALY
	LIVORNO, ITALY
	SAN REMO, ITALY
	LA SPEZIA, ITALY
	VENICE, ITALY
	TRIESTE, ITALY

1989	PORT
	SPLIT, YUGOSLAVIA
	DUBROVNIK, YUGOSLAVIA
	TARANTO, ITALY
	PALERMO, ITALY
	MESSINA, ITALY
	TAORMINA, ITALY
	PORTO TORRES, ITALY

1990	PORT
	BENIDORM, SPAIN
	ROTA, SPAIN
	TANGIER, MOROCCO
	PORT SAID, EGYPT
	ALEXANDRIA, EGYPT
	ALGIERS, ALGERIA
	TUNIS, TUNISIA
	GULF HAMMAMET, TUNISIA
	GULF OF GABES, TUNISIA
	SOUDA BAY, CRETE

1991	PORT
	PIRAEUS, GREECE
	KALAMATA, GREECE
	THESSALONIKI, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	VALETTA, MALTA
	LARNACA, CYPRUS

1992	PORT
	ANTALYA, TURKEY
	ISKENDERUN, TURKEY
	IZMIR, TURKEY
	ISTANBUL, TURKEY
	GOLCUK, TURKEY
	GULF OF SOLLUM

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.

B. Cruise reports were reviewed.

C. Navy personnel with current or previous area experience were interviewed.

D. A preliminary report was developed which included questions on various local conditions in specific harbors.

E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained (See section 3 references).

F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,

B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,

C. local wind wave conditions, and

D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2. CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

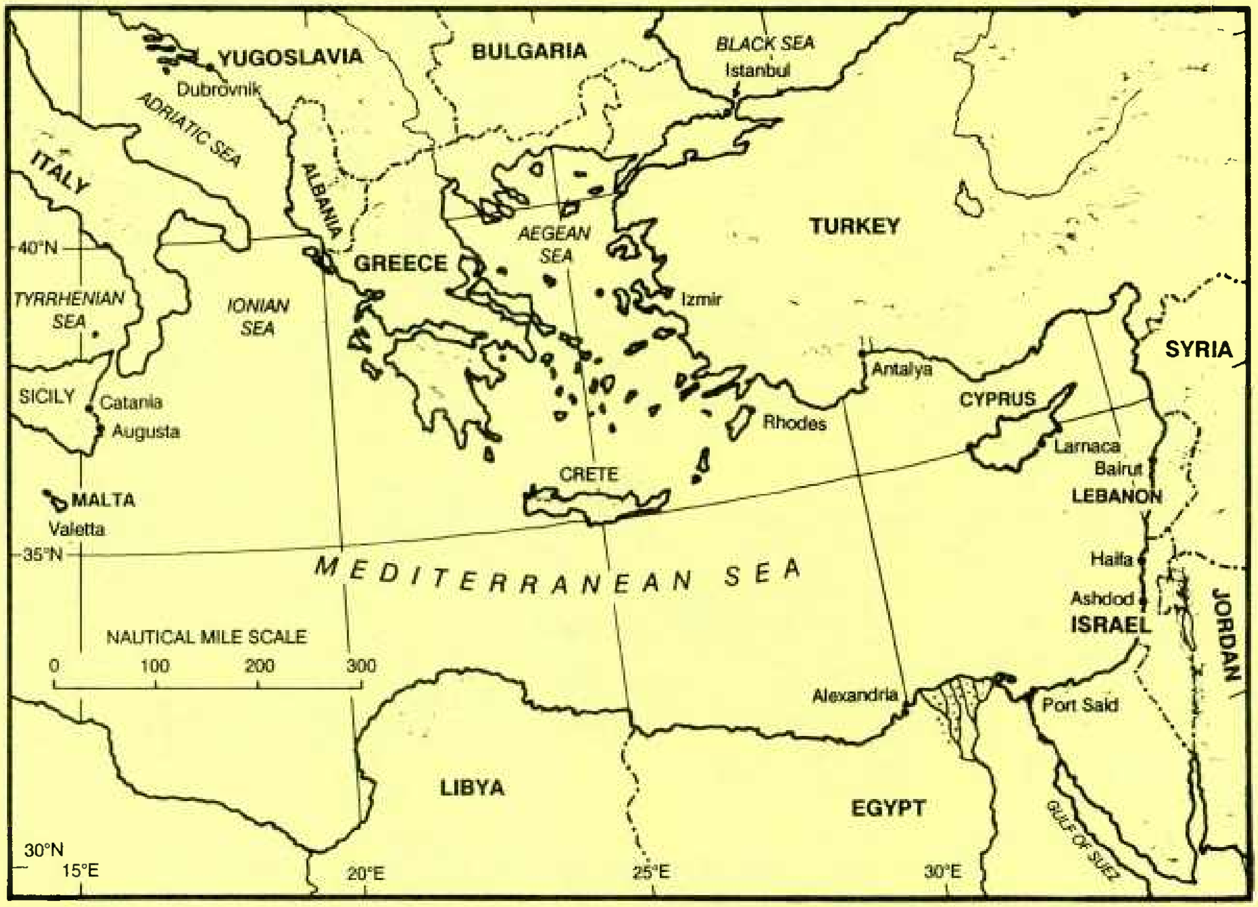
Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested precautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

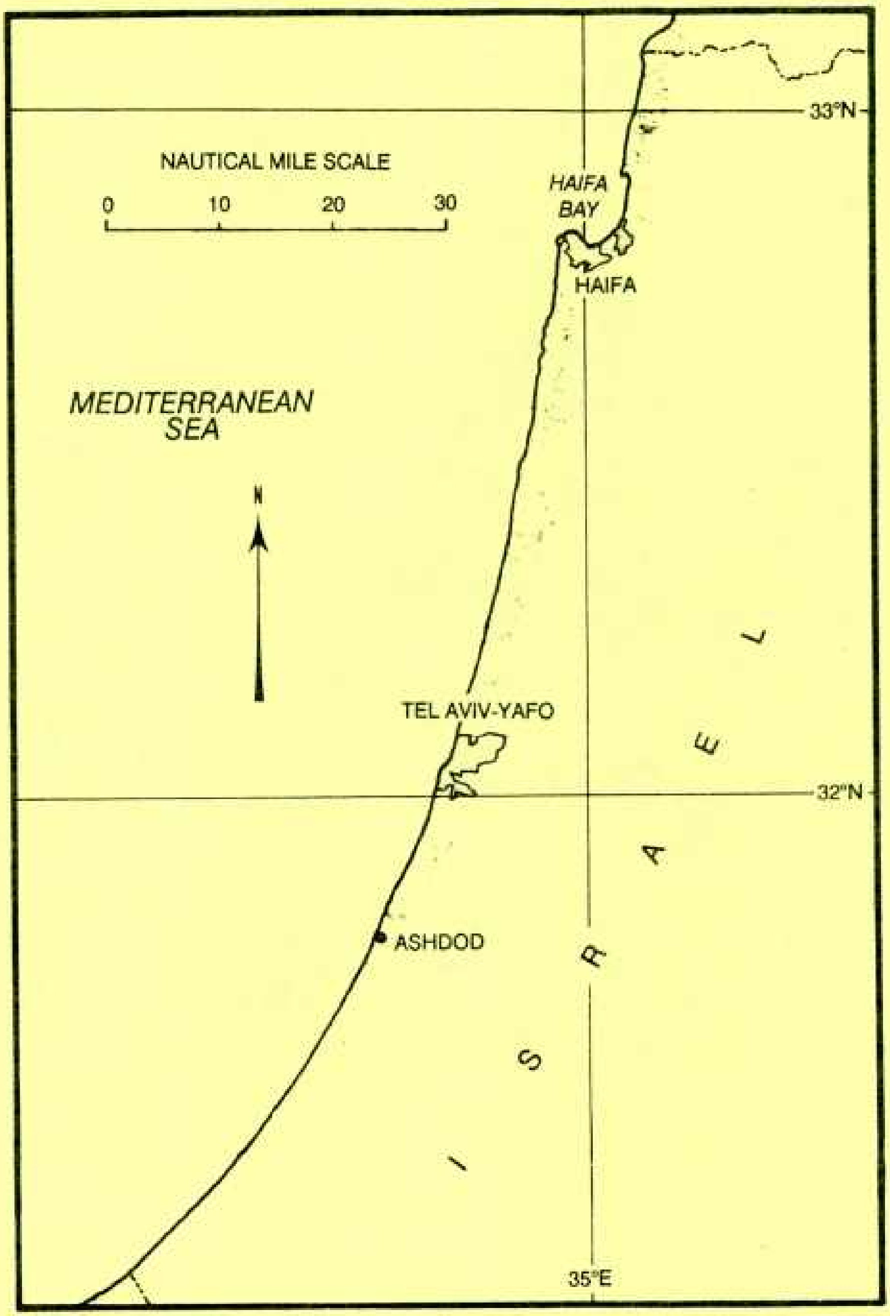
2. CAPTAIN'S SUMMARY

The Port of Haifa is located on the southern shore of Haifa Bay near 32.8°N, 35.0°E (Figure 2-1).



2-1. Eastern Mediterranean Sea.

Haifa is the most protected harbor on the Israeli coast. The southern position of Haifa Bay provides natural protection from waves from the northeast clockwise through west (Figure 2-2).

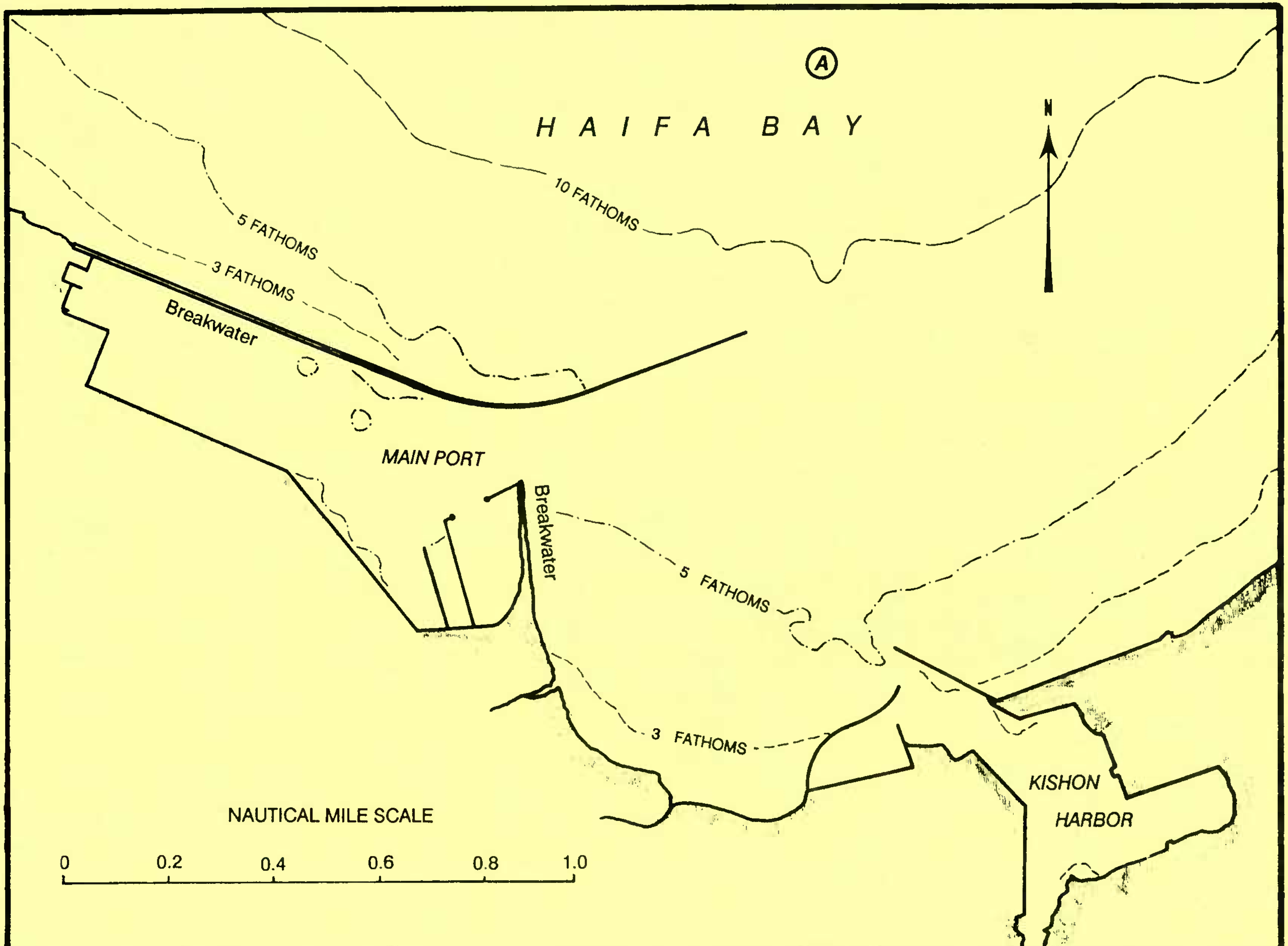


2-2. Coast of Israel.

Haifa harbor is defined and protected by two breakwaters. The main breakwater on the north is 9,326 ft (2826 m) long and the lee side breakwater on the east extends some 2525 ft (765 m) offshore (Figure 2-3). The main breakwater extends approximately 2600 ft (788 m) beyond the entrance. The entrance between the two breakwaters is 604 ft (183 m) wide and is about 40 ft (12 m) deep. Vessels with draft to 34 ft can be accommodated in Haifa harbor*. Kishon harbor is located about 5280 ft (1600 m) east of the entrance to the main harbor. Kishon harbor consists of an outer harbor basin about 1980 ft (600 m) formed by two breakwaters and a main channel about 3449 ft (1045 m) long. The entrance to Kishon harbor is 231 ft (70 m) wide and the harbor can accommodate vessels with drafts to 27 ft. Vessels with drafts of 45 ft can be accommodated at the container and bulk terminal located between the two harbors.

The anchorage area (marked with an 'A' - Figure 2-3) is seaward of the main breakwater. The bottom is composed of a relatively thin layer of fine sand (less than 2 ft) over soft clay. Holding quality is good. Waves greater than 13 ft (4 m) occur during extreme winter storms. The farther west a vessel is in the anchorage area the more subject it is to heavy swell. Increased scope should be used under heavy swell conditions. Breaking waves occur with heavy swell conditions in those areas with depths less than 18 ft (3 fathoms).

* Note: In March 1985, a navy vessel ran aground in Haifa Harbor. This ship's captain cautions that a sandbar exists in the harbor and may shift over a period of time. Check latest charts, Notice to Mariners, and proceed with caution.



2-3. Port of Haifa.

Astronomical tidal variations are slight in the Haifa Bay area (1-3 ft) and tidal currents are negligible. However, wave induced currents of 3 to 4 kt may be experienced at a distance of about 2/3 of the surf zone from the beach during storms.

The following is a Seasonal Summary of Hazardous Weather Conditions:

WINTER (November thru February)

* Winter storms bring strong winds, accompanied by swell.
* Bora occasionally extends to coast with force 8 to 9 westerly winds.
* Southerly Scirocco wind (warm in winter) brings poor visibility due to dust.
* Sixty percent of all strong winds occur in Dec-Feb.

SPRING (March thru May)

* Lows form off African coast moving toward Israel.
* Poorest visibilities occur in spring.

SUMMER (June thru September)

* Westerly Etesian winds reach gale force on rare occasions, accompanied by heavy swell.
* Scirocco (hot in summer) produces dust and low visibility.

AUTUMN (October)

* Short transition season. Winter starts at months end.

NOTE: For more detailed information on hazardous weather, see Summary Table 2-1, which contains specific hazardous conditions, vessel situations, and suggested precautionary/evasive action scenarios. Hazards for both inport and at anchorage are addressed.

Table 2-1. Summary of hazardous environmental conditions for the Port of Haifa, Israel.

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
1. Bora wind - Westerly force 8-9 (34-47 kt) following strong cold air outbreak over Aegean Sea. * Most common late winter.	Advance warning. * Cold outbreak must extend to above 850 mb level for gale force winds to reach coast of Israel.	(1) Anchored or in open sea.	(a) Vessels smaller than carriers. * Under extreme conditions enter Haifa Port, otherwise stay in Haifa Bay. (b) Carriers. * Under extreme conditions move to anchorage in Haifa bay, use extra scope at anchorage. (c) Swell heights increase in western portion of anchorage. * Select anchorage locations as far east as possible. (d) In western portion of anchorage vessels are inclined to lie across the swell. * Wind waves and swell likely from different directions.
		(2) In port.	(a) Carriers can not be serviced in Haifa Port. * All other vessels stay in port and increase moorings.
		(3) Small boats.	(a) Heavy swell in anchorage area. * Boating outside port will be restricted/cancelled. * Be aware of breaking seas inside about 18 ft depth contour. * Anchored vessels in western portions of anchorage tend to lie across the swell, along side operations of different length vessels will be hazardous. (b) Port provides protection from open sea waves. * If in port remain there and increase moorings.
2. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) over the eastern Mediterranean. * Summer condition resulting in heavy swell.	Advance warning. * Steepening pressure gradient between thermal low over Turkey and high over Balkans. * Resulting strong northwesterly winds out of Aegean Sea.	(1) Anchored or in open sea.	(a) Long period (9-12 sec) west to northwest swell. * Extreme heights of 15 to 18 ft, 8 to 12 ft more typical. * Average duration about 2 days in early (May-June) and late (September-October) summer and 4 days in July and August. * Typically at least one 5 day period per year and one 10 day period about once every six years in July-August. (b) Vessels smaller than carriers. * Under extreme conditions enter Haifa Port, otherwise stay in Haifa Bay. (c) Carriers. * Under extreme conditions move to anchorage in Haifa bay, use extra scope at anchorage. (d) Swell heights increase in western portion of anchorage. * Select anchorage locations as far east as possible. (e) In western portion of anchorage vessels are inclined to lie across the swell. * Wind waves and swell likely from different directions.
		(2) In port.	(a) Port provides protection from open sea swell. * Expect heavy swell and increased currents near entrance. (b) Carriers can not be serviced in Haifa Port. * All other vessels stay in port and increase moorings.
		(3) Small boats.	(a) Direction of long period swell and local waves likely to differ. * Small boats and larger vessels will be responding to different wave action. * Open sea operations/tending between vessels of various lengths will be hazardous. (b) Heavy swell in anchorage area. * Boating outside port will be restricted/cancelled. * Be aware of breaking seas inside about 18 ft depth contour. * Anchored vessels in western portions of anchorage tend to lie across the swell, along side operations of different length vessels will be hazardous. (c) Port provides protection from open sea waves. * If in port remain there and increase moorings.

Table 2-1. (Continued)

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
3. Migratory lows - Source region changes with season. Israeli coast experiences southerly wind (Sirocco) force 7-8 (28-40 kt) as low approaches, becoming westerly force 8-9 (34-47 kt). * Southern Aegean Sea Autumn and winter. * Cyprus Area Late autumn or early spring. * North Africa Spring desert depressions.	Advance warning. * Intensification of low crossing Italy. Tend to track eastward. * Intensification of migratory low due to cold outbreak over Turkey. Low tends to become stationary for a few days. * Develops over desert south of Atlas Mountains, normally moves northeastward just south of the North African coast especially in spring. Will normally track northeast if heat trough over Turkey is deeper than 1000 mb.	(1) Anchored or in open sea.	(a) Vessels smaller than carriers. * Under extreme conditions enter Haifa Port, otherwise stay in Haifa Bay. * Waves to 20 ft (6 m) likely in area. (b) Carriers. * Under extreme conditions move to anchorage in Haifa bay, use extra scope at anchorage. * Waves over 20 ft (>6 m) likely in area. (c) Swell heights increase in western portion of anchorage. * Select anchorage locations as far east as possible. (d) In western portion of anchorage vessels are inclined to lie across the swell. * Wind waves and swell likely from different directions.
		(2) In port.	(a) Carriers can not be serviced in Haifa Port. * All other vessels stay in port and increase moorings.
		(3) Small boats.	(a) Heavy swell in anchorage area. * Boating outside port will be restricted/cancelled. * Be aware of breaking seas inside about 18 ft depth contour. * Anchored vessels in western portions of anchorage tend to lie across the swell, along side operations of different length vessels will be hazardous. (b) Port provides protection from open sea waves. * If in port remain there and increase moorings.
4. Sea Breeze - * Late spring. * Summer. * Early autumn.	Daily occurrence.	(1) Small boats.	(a) Sea breeze starts about 1000 LST, reaches maximum by 1300-1400, and dies off rapidly after 1600, calm by 1830. In September lasts until midnight but weak. * Sea breeze effects generally limited to low chop. * Local wind waves generated by sea breeze will be out of phase with swell, vessels of different lengths will respond to different wave lengths.

Shallow water wave conditions have been computed for the anchorage area indicated on Figure 2-3. The anchorage is located about 1100 yd north of the end of the main breakwater near the 15 m depth contour. The wave conditions will be similar throughout the anchorage area, but with a general increase in swell height over the western position.

Table 2-2 provides the height ratio and direction of shallow water waves to be expected at the point when the deep water wave conditions are known. The Haifa Bay anchorage conditions are found by entering Table 2-2 with the forecast or known deep water wave direction and period. The height is determined by multiplying the deep water height by the ratio of shallow to deep height.

Example: Use of Table 2-2 for Haifa Bay Point A.
Deep water wave forecast as provided by a forecast center or a reported/observed deep water wave condition: 12 feet, 10 seconds, from 270°. The expected wave condition at Haifa Bay Point A as determined from Table 2-2: 6 feet, 10 seconds, from 300°

NOTE: Wave periods are a conservative property and remain constant when waves move from deep to shallow water, but speed, height, and steepness change.

Table 2-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 2-3 for location of the point).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

HAIFA BAY POINT A:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
270°	285°	300°	300°	310°	315°	305°
	.8	.8	.5	.5	.5	.6
300°	305°	310°	315°	315°	320°	320°
	.8	.8	.6	.6	.6	.6
330°	330°	330°	325°	325°	330°	335°
	.9	.6	.5	.5	.3	.6
360°	355°	345°	345°	335°	340°	340°
	.7	.4	.4	.6	.5	.4

The local wind generated wave conditions for the anchorage area identified as point A are given in Table 2-3. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing wave height, the time to fetch limited height will be shorter.

Table 2-3. Haifa Bay. Local wind waves for fetch limited conditions at point A (based on JONSWAP model).

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Point A.

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
SE 2 n mi	<2 ft	<2 ft	1-2/2 1	2/2-3 1	2/3 1
E 3 n mi	<2 ft	<2 ft	2/3 1	2-3/3 1	3/3 1
NNE 15 n mi	2-3/4 2-3	3-4/4 2	4/5 2	5/5 2	6/5 2

> Example for Point A:
>
> To the north-northeast (22.5°) there is about a 15 n mi fetch (Figure 2-2). Given a north-northeast wind at 24 kt for a period of 2 hours, the sea will have reached 3-4 feet with a period of 4 seconds. Wind waves will not grow beyond this condition unless the wind speed increases or the direction changes to one over a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

Climatological factors of shallow water waves, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in Table 2-4. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m).

Table 2-4. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 (1 m) ft and greater than 6.6 ft (2 m) by climatological season.

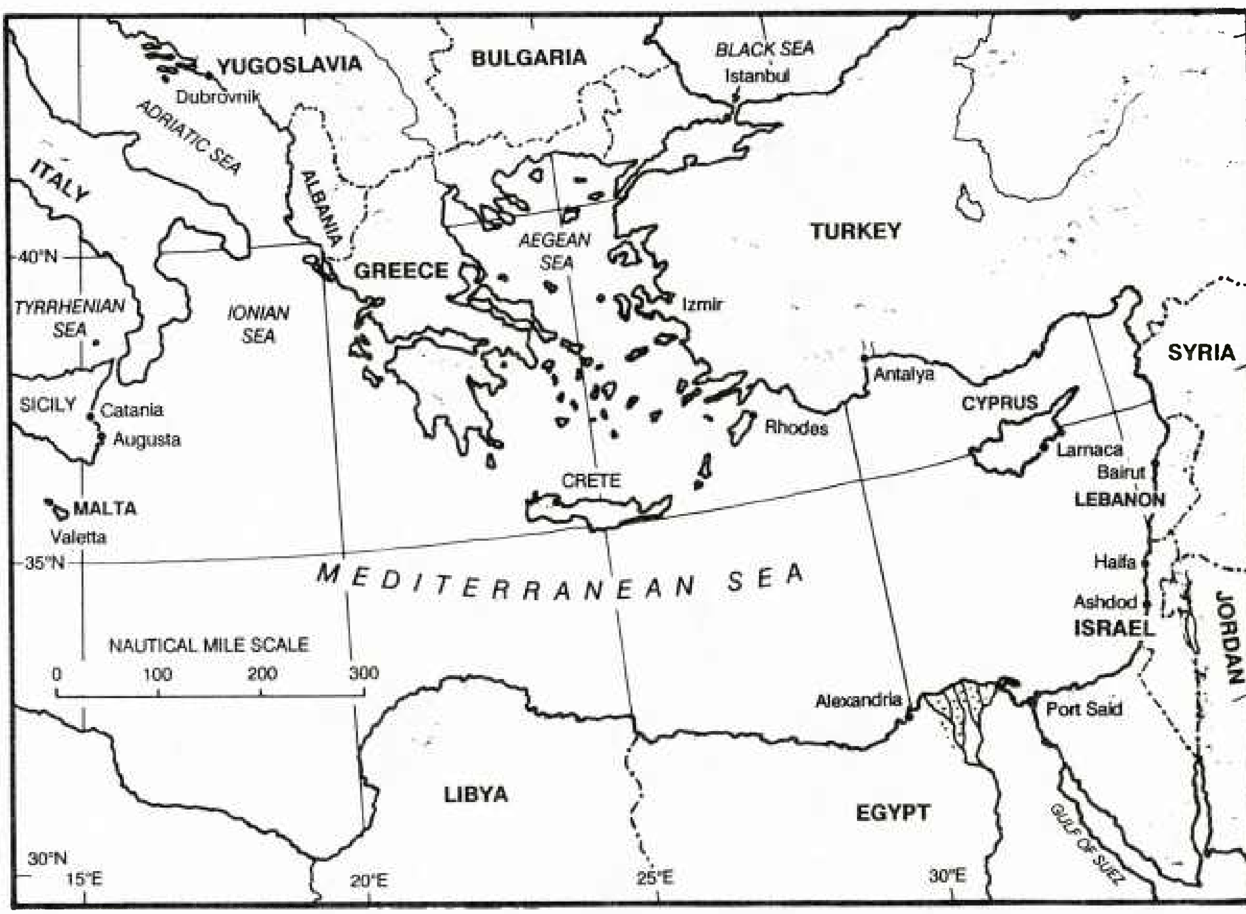
HAIFA BAY POINT A:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	22	18	23	7
Average Duration (hr)	15	20	27	17
Period Max Energy (sec)	9	9	9	9
>6.6 ft (2 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	2	1	< 1	0
Average Duration (hr)	11	8	12	NA
Period Max Energy (sec)	12	12	12	NA

3. GENERAL INFORMATION

This section expands on the material in the Captain's Summary. Some Figures and Tables are repeated. Table 3-4 provides a summary of hazards and actions by season.

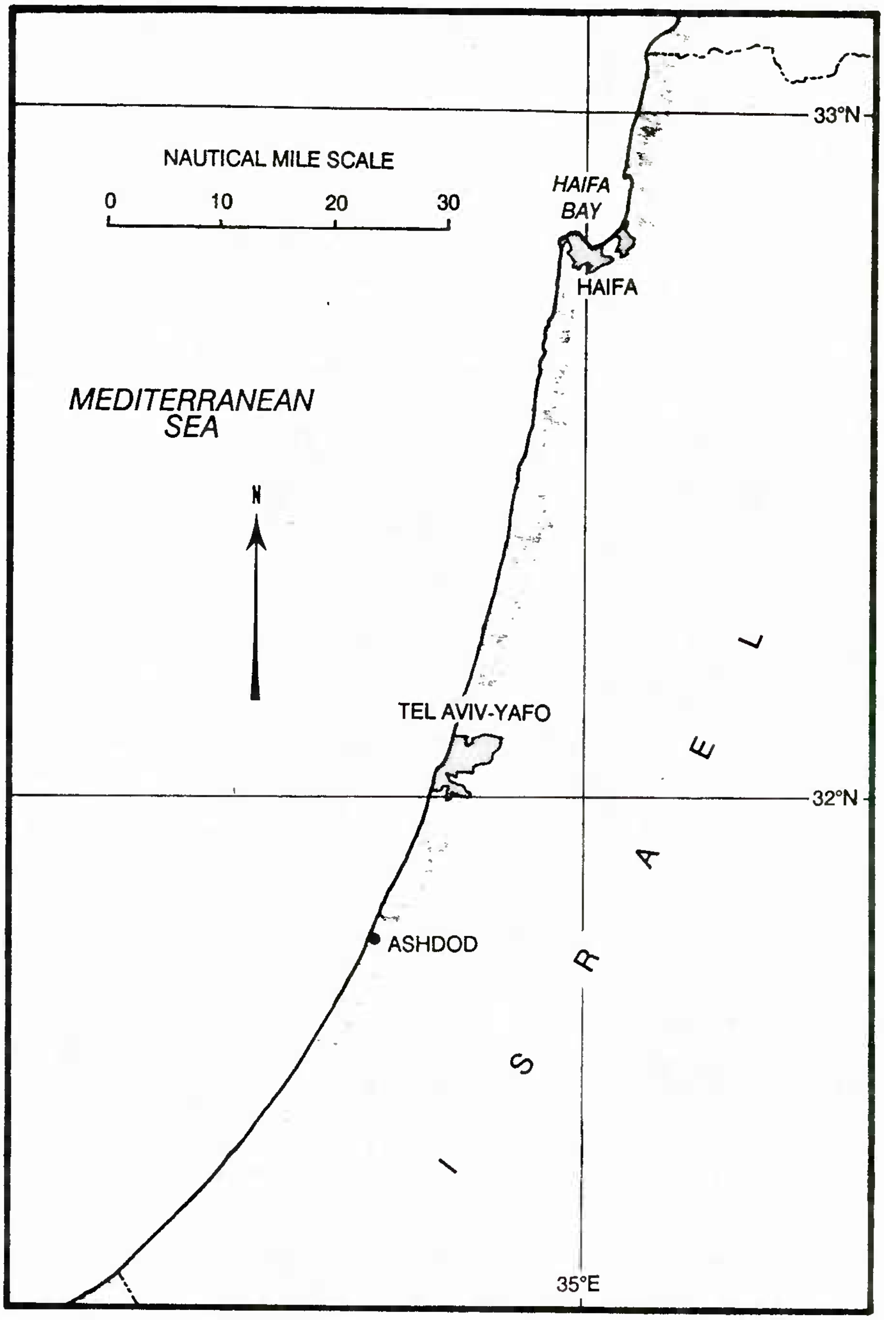
3.1 Geographic Location

The Port of Haifa is located on the southern shore of Haifa Bay near 32.8°N, 35.0°E (Figure 3-1).



3-1. Eastern Mediterranean Sea.

Haifa is the most protected harbor on the Israeli coast. The southern position of a Haifa Bay provides natural protection from waves from the northeast clockwise through west (Figure 3-2).

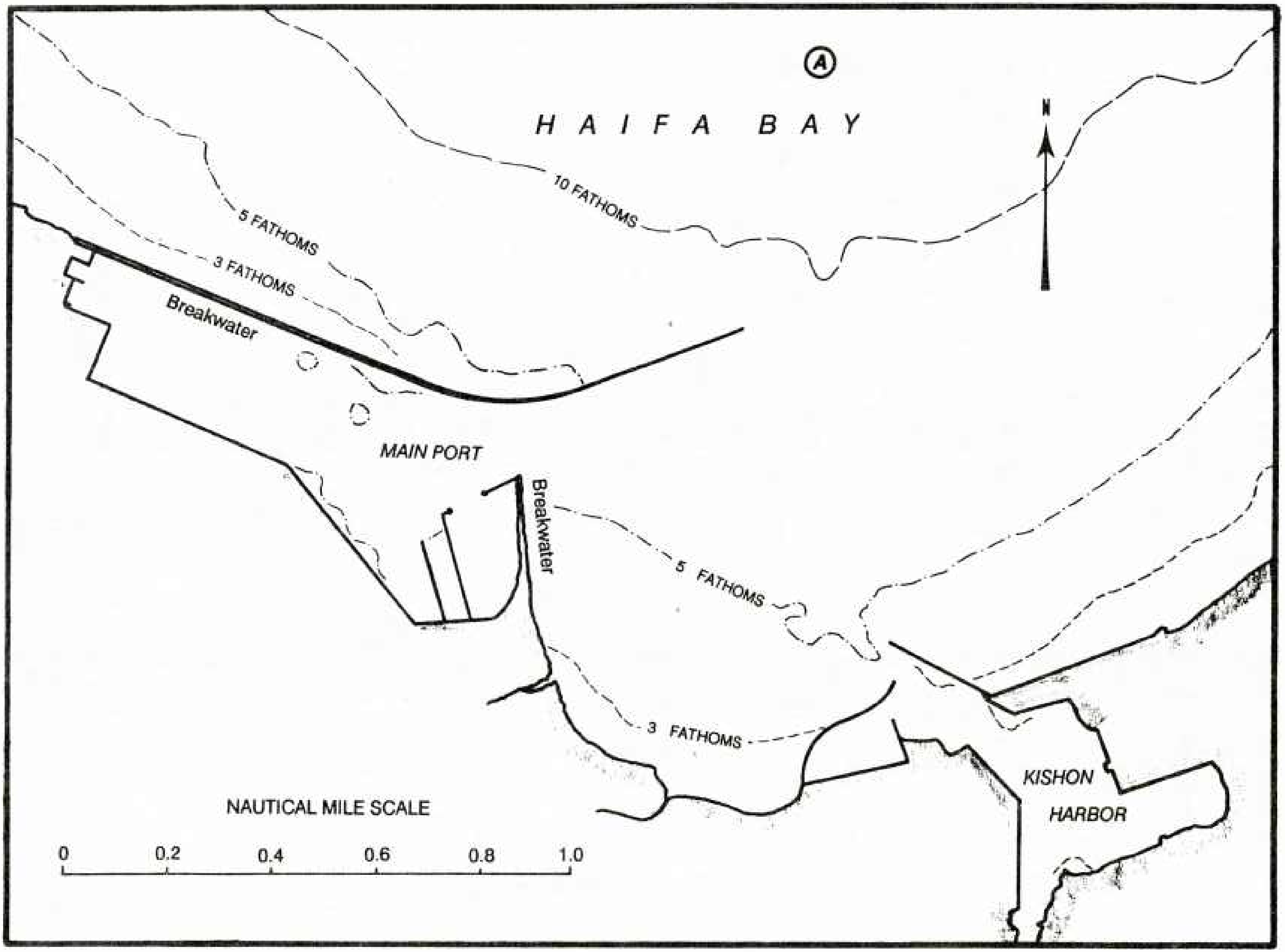


3-2. Coast of Israel.

Haifa harbor is defined and protected by two breakwaters. The main breakwater on the north is 9,326 ft (2826 m) long and the lee side breakwater on the east extends some 2525 ft (765 m) offshore (Figure 2-3). The main breakwater extends approximately 2600 ft (788 m) beyond the entrance. The entrance between the two breakwaters is 604 ft (183 m) wide and is about 40 ft (12 m) deep. Vessels with draft to 34 ft can be accommodated in Haifa harbor*. Kishon harbor is located about 5280 ft (1600 m) east of the entrance to the main harbor. Kishon harbor consists of an outer harbor basin about 1980 ft (600 m) formed by two breakwaters and a main channel about 3449 ft (1045 m) long. The entrance to Kishon harbor is 231 ft (70 m) wide and the harbor can accommodate vessels with drafts to 27 ft. Vessels with drafts of 45 ft can be accommodated at the container and bulk terminal located between the two harbors.

The anchorage area (marked with an 'A' - Figure 2-3) is seaward of the main breakwater. The bottom is composed of a relatively thin layer of fine sand (less than 2 ft) over soft clay. Holding quality is good. Waves greater than 13 ft (4 m) occur during extreme winter storms. The farther west a vessel is in the anchorage area the more subject it is to heavy swell. Increased scope should be used under heavy swell conditions. Breaking waves occur with heavy swell conditions in those areas with depths less than 18 ft (3 fathoms).

* Note: In March 1985, a navy vessel ran aground in Haifa Harbor. This ship's captain cautions that a sandbar exists in the harbor and may shift over a period of time. Check latest charts, Notice to Mariners, and proceed with caution.



3-3. Port of Haifa.

3.2 General Climate of the Mediterranean Coast of Israel

The following material and figures, except where otherwise noted, have been taken from Coastal and Marine Engineering Research Institute (Israel, 1987).

The Mediterranean coast of Israel is characterized by the so called "Mediterranean Sea climate". This climate is induced by the geographic location of the Israeli coast relative to the world pressure systems. Its characteristic properties are imposed by the subtropic highs. These highs, located between latitudes 25 and 30 degrees move with the sun, southward in winter and northward in summer. In summer these conditions lead to uniform weather with no precipitation.

In winter the region is located between two climatic areas, namely the subtropic highs in the South and the "conditioned weather" in the North. The conditioned weather area is characterized by moving lows (storms) which, when they succeed to penetrate into the Mediterranean, precipitation and bad weather conditions occur. Therefore, the winter is characterized by changing weather.

In addition to these general patterns defining the "Mediterranean Sea climate", the region is influenced by other geographic factors, which can be divided in two categories; bodies of air/source regions and monsoons.

Since the coast of Israel is located at the eastern boundary of the Mediterranean Sea, only westerly winds are wet (warm in winter and cool in summer). For other directions the winds will bring dry air (warm in summer and cold in winter).

Furthermore, the nearby African coasts, create a region of encounter between very different bodies of air - warm and dry terrestrial air from the South (desert) and cold and wet air from the North. Hence the coastal African region will be cyclogenetic, mainly in the transition seasons (spring and autumn). In summer the

presence of the subtropical low will diminish any activity in that region, while in winter the desert is not hot enough and the cyclo-generation capability is weak.

Finally, the Mediterranean coast of Israel can be under the influence of monsoons coming from either NE or SE. In both cases, the pressure systems generated improve the weather conditions in this region. These systems are the Indian monsoon in summer, the Siberian high in winter and the Sudan-Ethiopian low active during all seasons, but mainly in the transition seasons, especially autumn.

3.2.1 Summer Season

The typical atmospheric pressure at sea level in summer is presented in Figure 3-4.

3.2.2 Transition Seasons (Spring and Autumn)

The transition seasons are controlled by both the subtropical highs and by passing lows. Significant patterns during these seasons are the 'Red Sea trough' and the 'heat lows', both characterized by very hot and dry weather.

Typical development and path of heat lows is represented in Figure 3-5a and the map of atmospheric pressure at the peak of the low is represented in Figure 3-5b. A typical Red Sea trough is presented in Figure 3-6a, while in Figure 3-6b the low of the Red Sea trough has moved over the southeast Mediterranean Sea area.

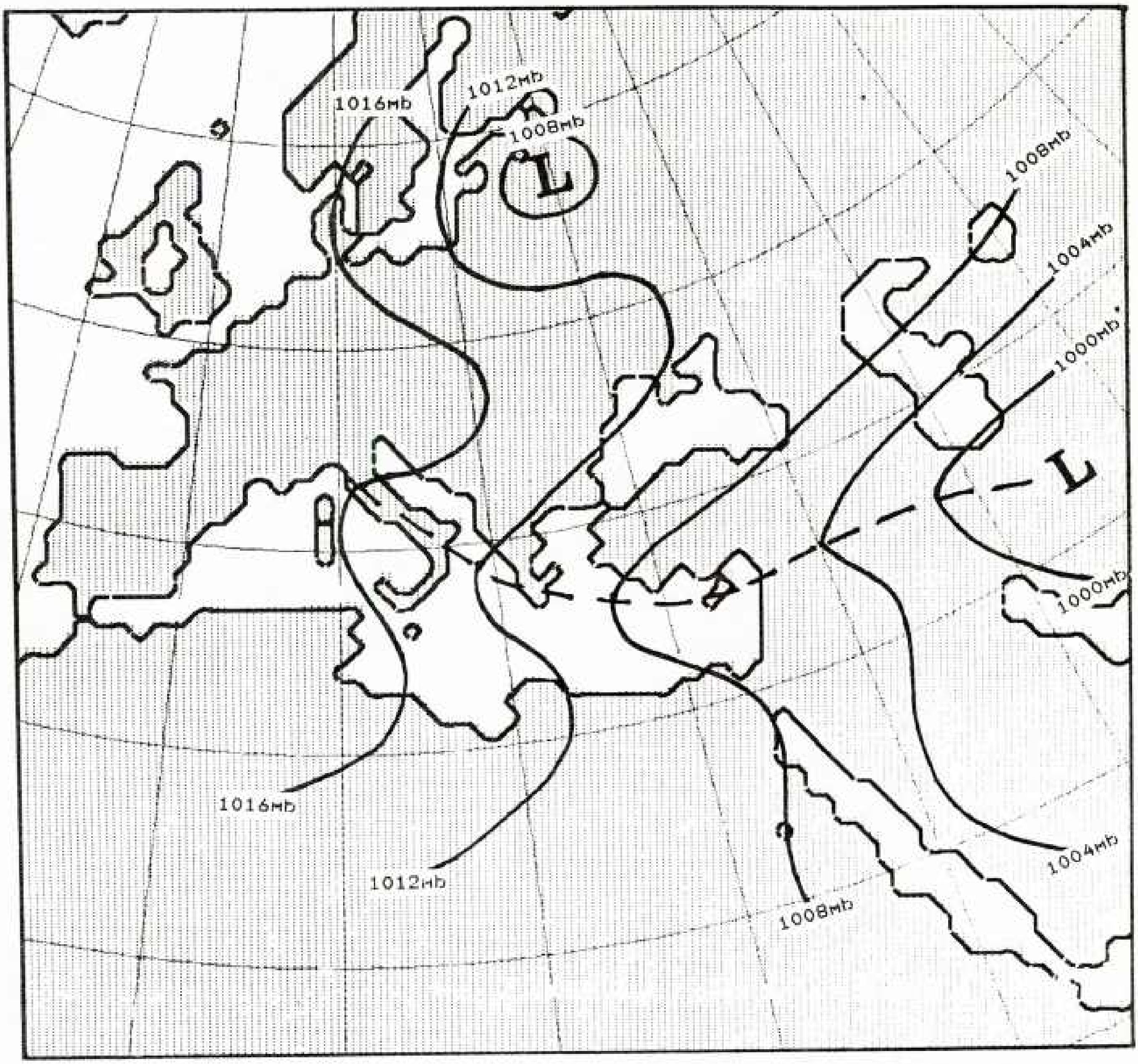


Figure 3-4. Typical synoptic surface pressure pattern for summer in the eastern Mediterranean Sea.

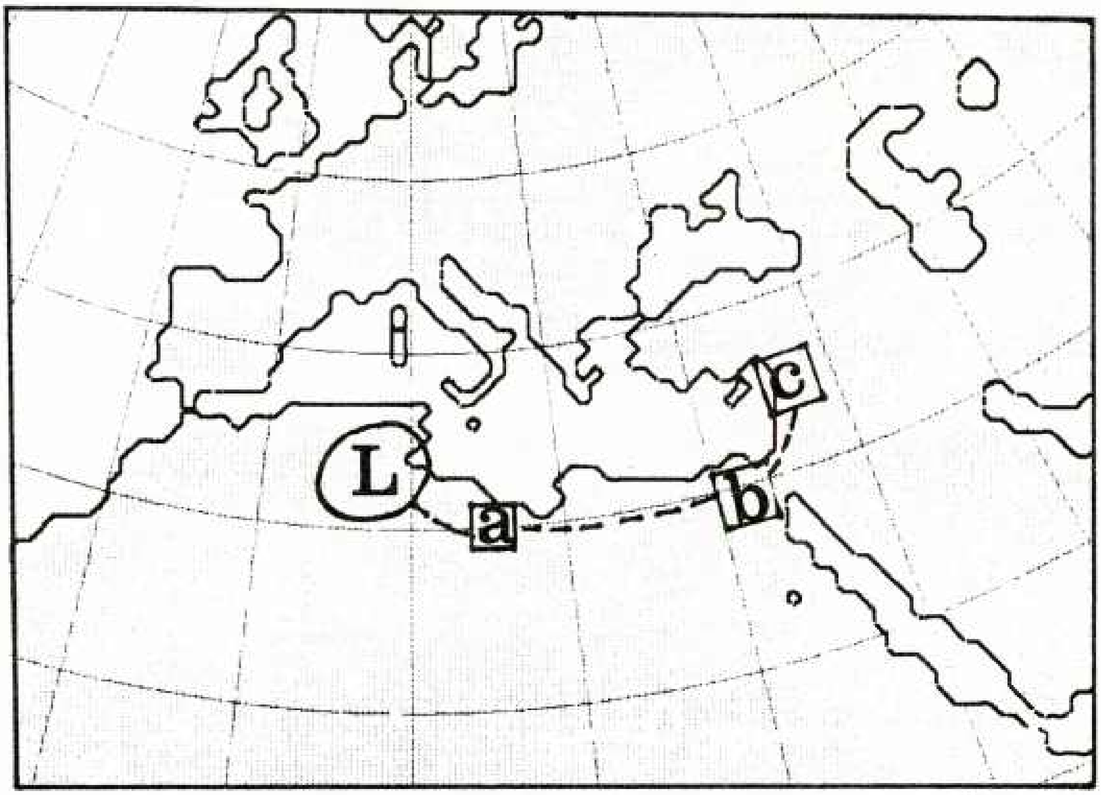


Figure 3-5a. Track of heat low during transition seasons. Position A - cloudy in eastern Mediterranean; B - peak intensity; C - hot weather subsides.

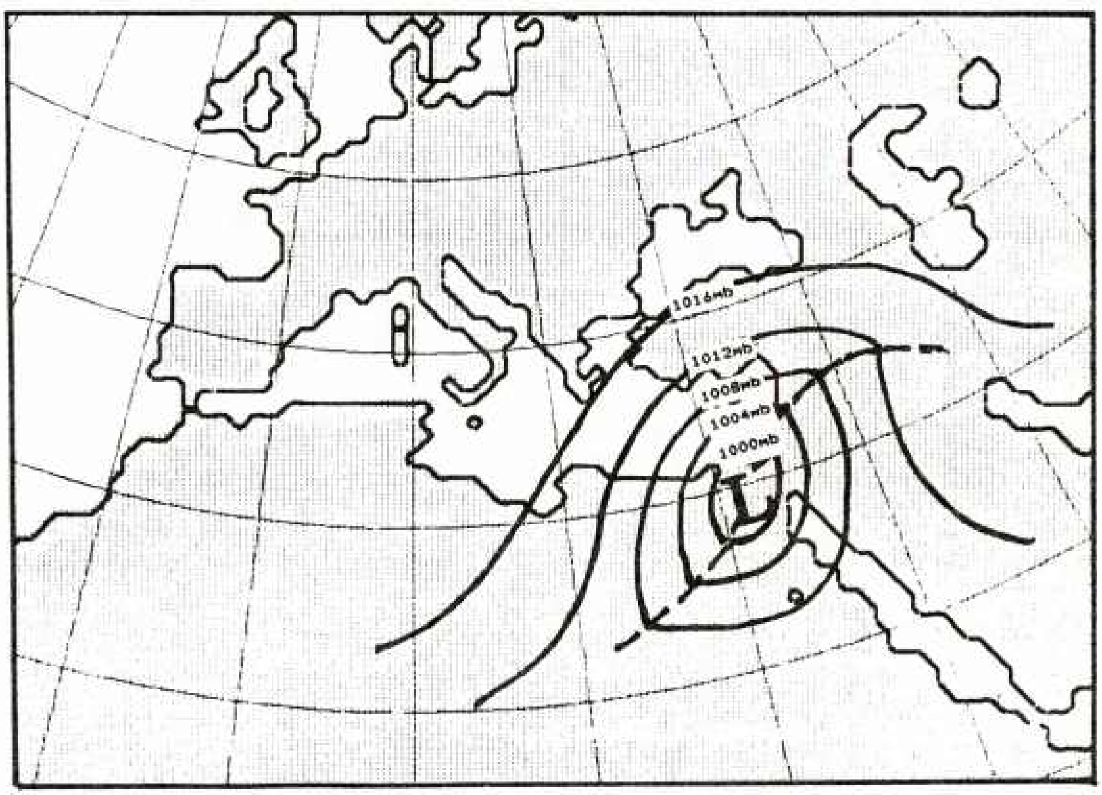


Figure 3-5b. Peak intensity of heat low during transition seasons.

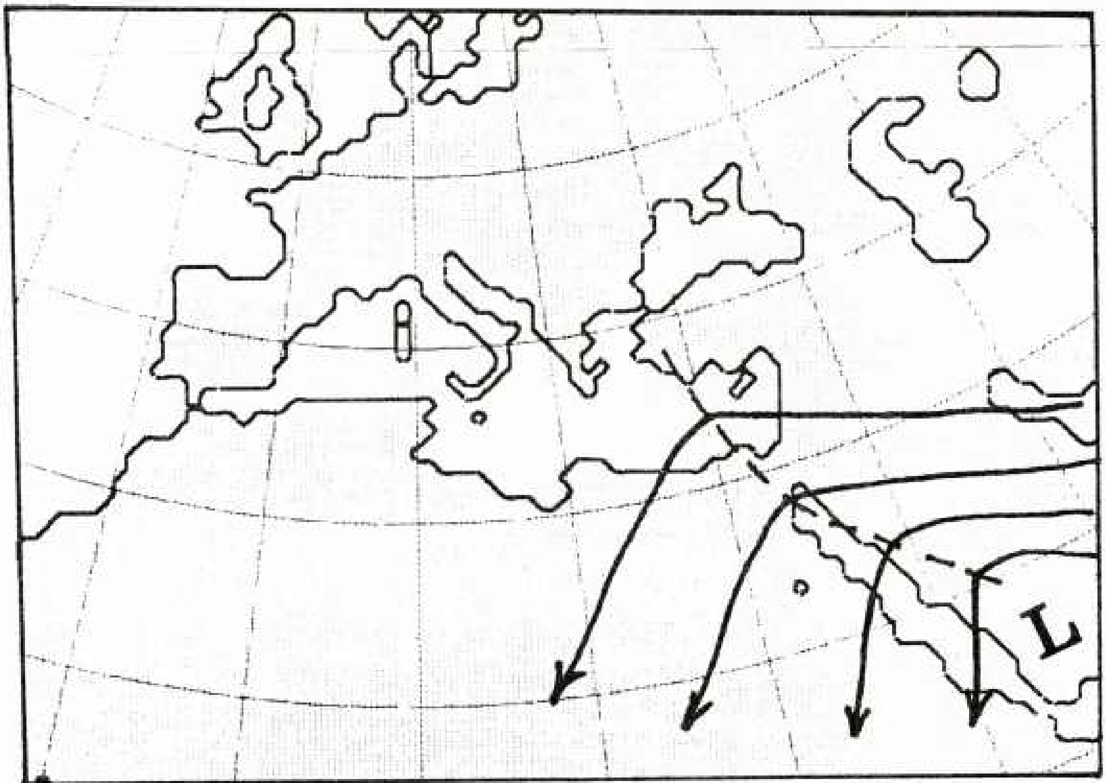


Figure 3-6a. Red Sea trough with western axis - transition seasons.

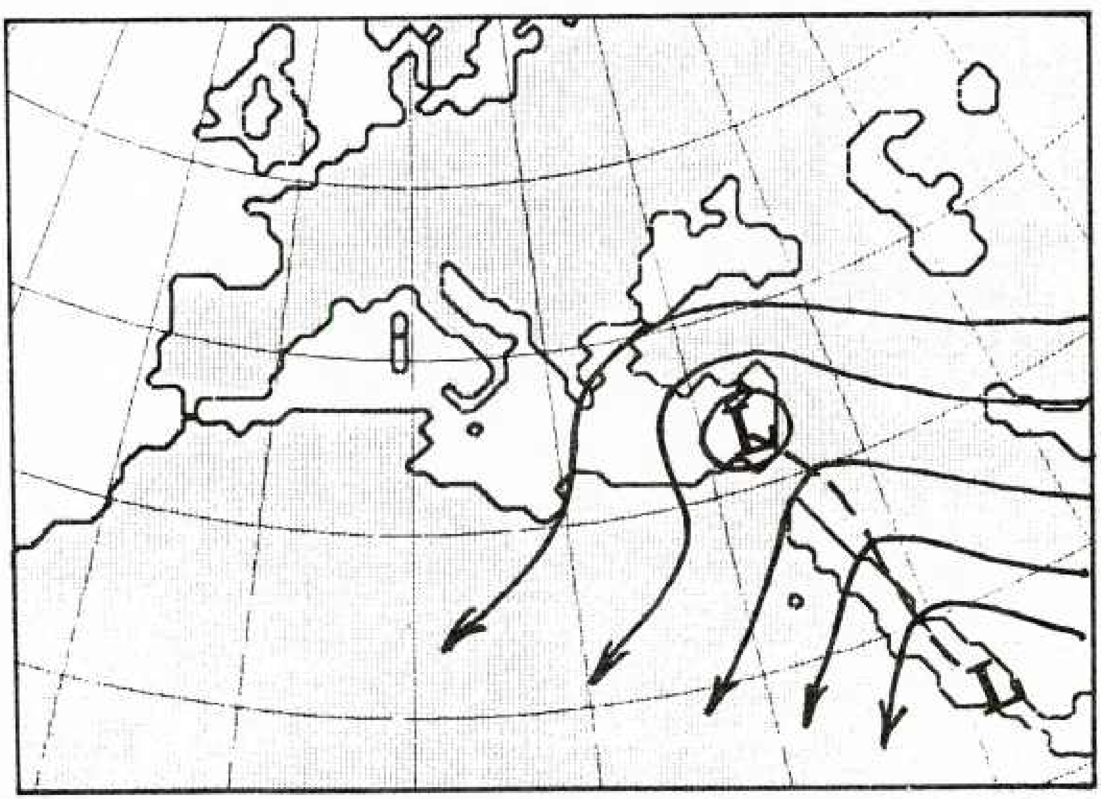


Figure 3-6b. Red Sea trough with closed low over the eastern Mediterranean - transition seasons.

3.2.3 Winter Season

Winter is characterized by changing weather, hence it is difficult to describe a representative condition. Nevertheless, certain situations lead to well defined and characteristic weather.

The most significant is the Mediterranean Sea low which originates from the strong Icelandic low, present the year around. The latter originates from the encounter between very cold polar air and the warm air raising in the area between England and Iceland due to the Gulfstream. This encounter leads to the creation of a strong source of cyclogenesis. The Mediterranean Sea low migrates in a southeasterly direction as indicated by the arrows in Figure 3-7. During its migration, the low weakens then it strengthens again near Italy.

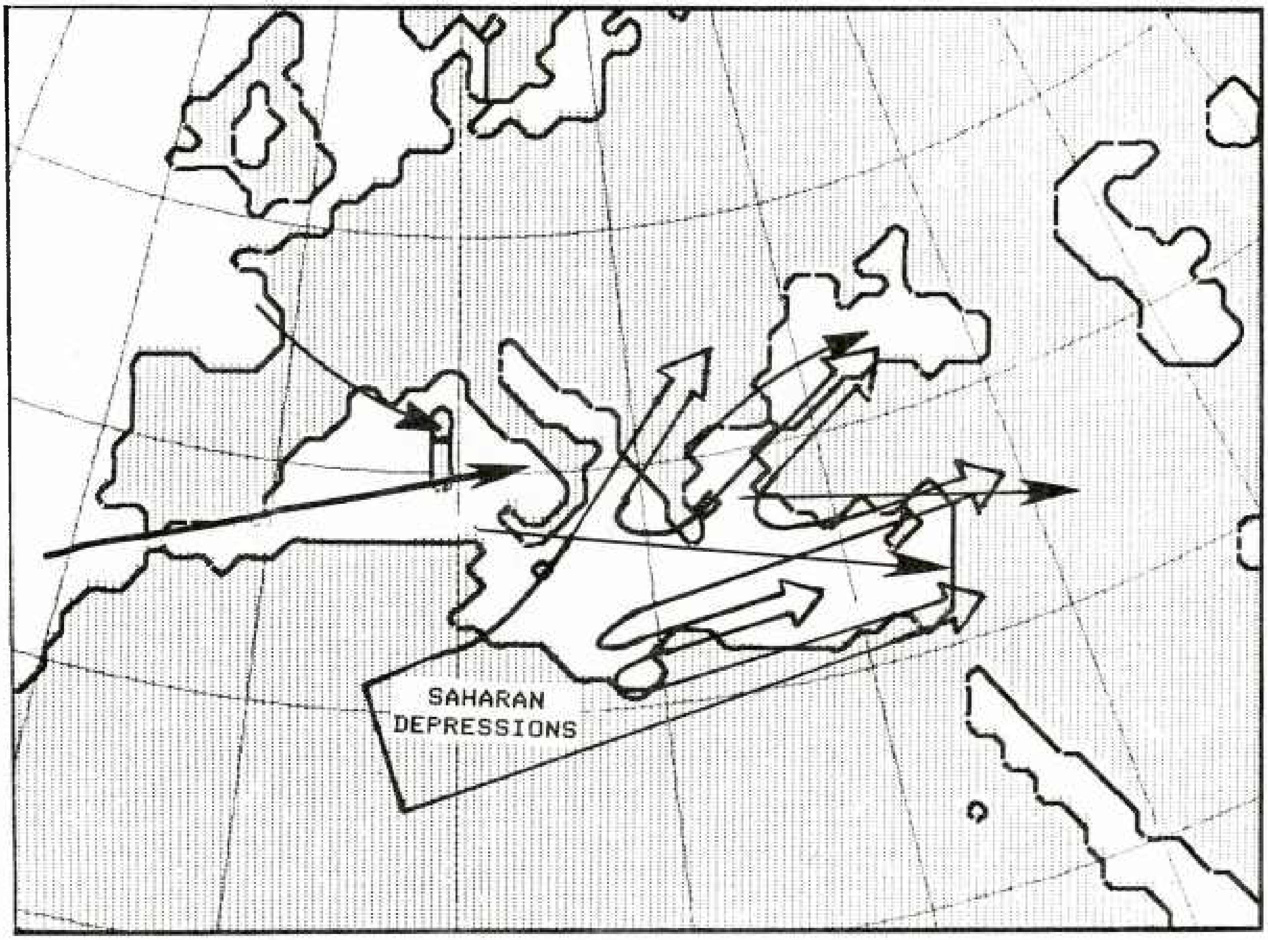


Figure 3-7. Typical storm tracks in the Mediterranean - winter season (after Reiter, 1975).

3.3 Local Wind Regimes

The following material on local wind regimes has been excerpted from Brody and Nestor (1980).

Etesian Winds

The etesian is a northerly to westerly wind that occurs during the summer over the Aegean Sea and eastern Mediterranean Sea. In the extreme eastern Mediterranean, off Israel, the etesians are westerly and normally less than gale force. The weather associated with the etesian is generally dry with good visibilities. Because of the long overwater trajectory of the air, cumulus clouds are likely. The etesian results from a combination of the following:

-- The monsoonal effect during the summer that leads to a low pressure trough over Turkey with higher pressure over the adjacent water surface.

-- Synoptic disturbances that lead to anti-cylogenesis over the Balkans. Cold air in the anticyclone following frontal passages appears to be the main cause of gale force etesians.

-- A jet-effect wind increase caused by channeling of the air between islands.

-- Mountains oriented perpendicular to the etesian which, under strong inversion conditions, block the flow and give calm seas in the lee. Strong winds are usually found only offshore from coastal valleys.

Bora

The bora is a cold, fall wind most common along the Yugoslavian coast. However, it can also occur over the Aegean Sea occasionally extending into the eastern Mediterranean. This extension of the bora from the Aegean Sea is associated with the large scale patterns over the eastern Atlantic and Europe which cause strong cold outbreaks over the Aegean Sea and Greece. The direction of the bora is usually northerly near Crete,

becoming westerly off the coast of Israel. Weather associated with the bora in the eastern Mediterranean depends on the length of the overwater trajectory of the cold, initially dry air. Since the cold air has a long overwater track and picks up moisture from the relatively warm water surface, convective cloudiness and some showers can be expected.

Sirocco

The sirocco is a southeasterly to southwesterly wind over the Mediterranean originating over North Africa. Because the air's source regions are desert, the sirocco is extremely dry at its source, warm in winter, and hot in spring and summer. In the eastern Mediterranean, the sirocco originates to the south over the deserts of Libya and Egypt and over the Arabian desert to the southeast. When the source is the Arabian desert, the direction of the sirocco is often southeasterly along the Israeli coast.

Weather associated with the sirocco in the coastal areas of Israel is usually dry with visibilities occasionally poor in blowing sand and/or dust. The dust cloud layer tends to be shallow and because of the strong surface inversion produced over the water (especially in spring), anomalous radar and radio propagation are likely.

3.4 Wind Climate

Mariners should be aware that all wind records used in this study are from land stations and that a ratio of 1.6:1 has been found to be a representative ratio for estimating maximum winds over open water areas from adjacent land reports (Hsu, 1981).

The following wind climatology statistics have been taken from Coastal and Marine Engineering Research Institute (Israel, 1987).

3.4.1 Intensity Distribution

light winds (less than 10 knots)	- 61%	of the time
fresh winds (11 to 21 knots)	- 37%	of the time
strong winds (22 to 33 knots)	- 1.5%	of the time
winds stronger than 33 knots	- 1%	of the time

3.4.2 Direction Distribution

57% of the fresh winds are from the W-NW-N directions
35% of the fresh winds are from the E-SE-S directions
46% of the strong winds are from the W direction
35% of the strong winds are from the E-SE-S directions

3.4.3 Diurnal Distribution

61% of the strong winds are during the day, 06-09-12-15 GMT
39% of the strong winds are during the night, 18-21-00-03 GMT

3.4.4 Seasonal Distribution

97% of the strong winds are between Nov and Mar
72% of the strong winds are between Dec and Feb

3.5 Visibility

The following climatology statistics have been taken from Coastal and Marine Engineering Research Institute (Israel, 1987).

3.5.1 Annual Distribution

good visibility (>6 km)	- 90%	of the time
intermediate visibility (1-5 km)	- 9%	of the time
bad visibility (<1000 m)	- 1%	of the time
extremely bad visibility (<100 m)	- 0.4%	of the time

3.5.2 Diurnal Distribution

73% of the intermediate visibility conditions are at 00-03-06 GMT
92% of the bad visibility conditions are at 00-03-06 GMT

3.5.3 <u>Seasonal Distribution</u>

70% of the extremely bad visibility conditions occur during the period April–June

3.6 <u>Shallow Water Wave Climate</u>

Shallow water wave conditions have been computed for the anchorage area indicated on Figure 3-3. The anchorage is located about 1100 yd north of the end of the main breakwater near the 15 m depth contour. The wave conditions will be similar throughout the anchorage area, but with a general increase in swell height over the western position.

<u>Table 3-1</u> provides the height ratio and direction of <u>shallow water waves</u> to be expected at the point <u>when the deep water wave conditions are known</u>. The Haifa Bay anchorage conditions are found by entering Table 3-1 with the forecast or known deep water wave direction and period. The height is determined by multiplying the deep water height by the ratio of shallow to deep height.

Example: Use of Table 3-1 for Haifa Bay Point A.
<u>Deep water wave forecast</u> as provided by a forecast center or a <u>reported/observed</u> deep water wave condition:
12 feet, 10 seconds, from 270°.
<u>The expected wave condition at Haifa Bay Point A</u> as determined from Table 3-1:
6 feet, 10 seconds, from 300°

<u>NOTE</u>: Wave periods are a conservative property when waves move from deep to shallow water, but speed, height, and steepness change.

Table 3-1. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of the point).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

HAIFA BAY POINT A:

Period (sec)	6	8	10	12	14	16
Deep Water Direction	Shallow Water Direction and Height Ratio					
270°	285°	300°	300°	310°	315°	305°
	.8	.8	.5	.5	.5	.6
300°	305°	310°	315°	315°	320°	320°
	.8	.8	.6	.6	.6	.6
330°	330°	330°	325°	325°	330°	335°
	.9	.6	.5	.5	.3	.6
360°	355°	345°	345°	335°	340°	340°
	.7	.4	.4	.6	.5	.4

The local wind generated wave conditions for the anchorage area identified as point A are given in Table 3-2. All heights refer to the significant wave height (average of the highest 1/3 waves). Enter the local wind speed and direction in this table to obtain the minimum duration in hours required to develop the indicated fetch limited sea height and period. The time to reach fetch limited height is based on an initial flat ocean. When starting from a pre-existing wave height, the time to fetch limited height will be shorter.

Table 3-2. Haifa Bay. Local wind waves for fetch limited conditions at point A (based on JONSWAP model).

<u>Format:</u> height (feet)/period (seconds)
time (hours) to reach fetch limited height

<u>Point A.</u>

Direction and Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
SE 2 n mi	<2 ft	<2 ft	1-2/2 1	2/2-3 1	2/3 1
E 3 n mi	<2 ft	<2 ft	2/3 1	2-3/3 1	3/3 1
NNE 15 n mi	2-3/4 2-3	3-4/4 2	4/5 2	5/5 2	6/5 2

<u>Example for Point A:</u>

To the north-northeast (22.5°) there is about a 15 n mi fetch (Figure 3-2). Given a north-northeast wind at 24 kt for a period of 2 hours, the sea will have reached 3-4 feet with a period of 4 seconds. <u>Wind waves</u> will not grow beyond this condition <u>unless</u> the wind speed increases or the direction changes to one over a longer fetch length. If the wind waves are superimposed on deep water swell, the combined height may change in response to changing swell conditions. Wind wave directions are assumed to be the same as the wind direction.

<u>Climatological factors of shallow water waves</u>, as described by percent occurrence, average duration, and period of maximum energy (period at which the most energy is focused for a given height), are given in <u>Table 3-3</u>. See Appendix A for discussion of wave spectrum and energy distribution. These data are provided by season for two ranges of heights: greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m).

Table 3-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 (1 m) ft and greater than 6.6 ft (2 m) by climatological season.

HAIFA BAY POINT A:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	22	18	23	7
Average Duration (hr)	15	20	27	17
Period Max Energy (sec)	9	9	9	9
>6.6 ft (2 m)	NOV-FEB	MAR-MAY	JUN-SEP	OCT
Occurrence (%)	2	1	< 1	0
Average Duration (hr)	11	8	12	NA
Period Max Energy (sec)	12	12	12	NA

3.7 Tides and Water Levels

Astronomical tidal variations are slight in the Haifa Bay area (1-3 ft) and tidal currents are negligible. However, wave induced currents of 3 to 4 kt may be experienced at a distance of about 2/3 of the surf zone from the beach during storms.

3.8 General Currents

A general current due to the water mass circulation in the Mediterranean is encountered the year around. Its activity is observed mainly in the offshore region beyond contour line of 20 m depth. Its direction is anticlockwise and parallel to the coastline and its mean velocity of about 1/4 to 1/2 knot.

3.8.1 Wave Currents

Wave induced currents occur inside the breaker zone, flowing mainly parallel to the coastline but

sometimes also narrow currents flowing offshore may occur (rip currents). The maximum theoretical value of the longshore current may reach 3 to 4 knots during storms at a distance of about 2/3 of the surf zone measured from the shoreline. However, outside the surf zone the longshore current diminishes rapidly to a few inches/second at about 15 m water depth.

3.9 Sea Bottom Description

The sea bottom of the Haifa bay in the region opposite the main breakwater is composed of a relatively shallow layer of fine sand (0.2-0.5 m) beneath which soft clay is found. The anchorage holding capacity depends on the type and size of anchors used.

3.10 Summary of Problems, Actions, and Indicators

The following pages present Table 3-4 which discusses specific hazards and their causes and suggest evasive action.

Table 3-4. Potential problem situations at Port of Haifa - ALL SEASONS

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
1. Anchored. Most common late Winter occurs Spring and Autumn	a. Bora wind - Becomes westerly, force 8-9 (37-47 kt) off coast of Israel.	a. High sea and winds at anchorage and throughout Haifa Bay. 1.) Southern bay provides maximum protection of any regional location. 2.) Vessels that can be accommodated should berth in Haifa port and use storm moorings.	a. Result of deep cold air outbreak over Aegean Sea. 1.) Strong northwesterly flow channeled east of Crete and becomes westerly over eastern Mediterranean. 2.) For Bora caused winds to reach the Israeli coast area, cold air over southern Aegean Sea must extend above 850 mb level.
Summer condition	b. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) in eastern Mediterranean.	b. Long period swell (9-12 sec) from the west to northwest reaches coastal waters of Israel. Heights of 8 to 12 ft (2-3 m) are typical, extreme heights of 15 to 18 ft occur, direction of swell and local wind waves likely to differ. 1.) Move as far east as possible in the anchorage area to minimize heavy swell action. 2.) Be aware of varying response to waves by vessels of different lengths.	b. Result of steepening pressure gradient between thermal low over Turkey and high pressure over the Balkans. 1.) The average duration is about 2 days during early (May-June) and late (September-October) summer and about 4 days during July and August. 2.) Typically at least one 5 day period each year and one 10 day period about every 6 years during July and August.
All Seasons	c. Migratory lows - Begins as southerly (Sirocco) force 7-8 (28-40 kt) becoming westerly force 8-9 (34-47 kt) with waves over 20 ft (6 m) during extreme conditions.	c. High sea and winds at anchorage and throughout Haifa Bay. 1.) Southern bay provides maximum protection of any regional location. 2.) Vessels that can be accommodated should berth in Haifa port and use storm moorings.	c. The source region of migratory lows varies with season. 1.) Migratory mid latitude lows often intensify over the southern Aegean Sea after crossing Italy, this occurs most often during autumn and winter. 2.) During late autumn and early spring these same migratory lows at times become nearly stationary near Cyprus and intensify again when a strong cold air outbreak occurs over Turkey. 3.) All migratory lows and fronts should be closely monitored for new developments. Upper level short wave troughs and low level cold air outbreaks are features most often associated with redevelopment. 4.) Lows forming over the desert south of the Atlas Mountains of North Africa tend to track northeastward out of the Gulf of Sabes. During spring some of these North African lows track eastward and remain over land until reaching the eastern Mediterranean. These result in extensive dust layers aloft as well as heavy seas and winds off the Israeli coast. The highest winds in these cases tend to be in the northwest sector (over open sea) of the lows.

Table 3-4. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
2. Arriving/Departing. Most common late Winter occurs Spring and Autumn	a. Bora wind - Becomes westerly, force 8-9 (37-47 kt) off coast of Israel.	a. High sea and winds at anchorage and throughout Haifa Bay. 1.) All vessels should delay arrival until conditions subside. 2.) Make departures early or delay until conditions subside. 3.) Reduce speed of advance if underway.	a. Result of deep cold air outbreak over Aegean Sea. 1.) Strong northwesterly flow channeled east of Crete and becomes westerly over eastern Mediterranean. 2.) For Bora caused winds to reach the Israeli coast area, cold air over southern Aegean Sea must extend above 850 mb level.
Summer condition	b. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) in eastern Mediterranean.	b. Long period swell (9-12 sec) from the west to northwest reaches coastal waters of Israel. Heights of 8 to 12 ft (2-3 m) are typical, extreme heights of 15 to 18 ft occur, direction of swell and local wind waves likely to differ. 1.) All vessels should delay arrival. 2.) Depart early for open sea or Haifa Bay. 3.) Direction of swell and other local waves likely to differ. Delay or take extra care in close operations of varying size vessels/craft.	b. Result of steepening pressure gradient between thermal low over Turkey and high pressure over the Balkans. 1.) The average duration is about 2 days during early (May-June) and late (September-October) summer and about 4 days during July and August. 2.) Typically at least one 5 day period each year and one 10 day period about every 6 years during July and August.
All Seasons	c. Migratory lows - Begins as southerly (Sirocco) force 7-8 (28-40 kt) becoming westerly force 8-9 (34-47 kt) with waves over 20 ft (6 m) during extreme conditions.	c. High sea and winds at anchorage and throughout Haifa Bay. 1.) All vessels should delay arrival until conditions subside. 2.) Make departures early or delay until conditions subside. 3.) Reduce speed of advance if underway.	c. The source region of migratory lows varies with season. 1.) Migratory mid latitude lows often intensify over the southern Aegean Sea after crossing Italy, this occurs most often during autumn and winter. 2.) During late autumn and early spring these same migratory lows at times become nearly stationary near Cyprus and intensify again when a strong cold air outbreak occurs over Turkey. 3.) All migratory lows and fronts should be closely monitored for new developments. Upper level short wave troughs and low level cold air outbreaks are features most often associated with redevelopment. 4.) Lows forming over the desert south of the Atlas Mountains of North Africa tend to track northeastward out of the Gulf of Gabes. During spring some of these North African lows track eastward and remain over land until reaching the eastern Mediterranean. These result in extensive dust layers aloft as well as heavy seas and winds off the Israeli coast. The highest winds in these cases tend to be in the northwest sector (over open sea) of the lows.

Table 3-4. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
3. Small boats. Most common late Winter occurs Spring and Autumn	a. Bora wind - Becomes westerly, force 8-9 (37-47 kt) off coast of Israel.	a. High sea and winds at anchorage and throughout Haifa Bay. 1.) Stay in port, add mooring lines. 2.) If at sea in Haifa Bay return to Haifa port.	a. Result of deep cold air outbreak over Aegean Sea. 1.) Strong northwesterly flow channeled east of Crete and becomes westerly over eastern Mediterranean. 2.) For Bora caused winds to reach the Israeli coast area, cold air over southern Aegean Sea must extend above 850 mb level.
Summer condition	b. Etesian wind - Northerly force 7-8 (28-40 kt) over Aegean Sea becoming westerly force 5-6 (17-27 kt) in eastern Mediterranean.	b. Long period swell (9-12 sec) from the west to northwest reaches coastal waters of Israel. Heights of 8 to 12 ft (2-3 m) are typical, extreme heights of 15 to 18 ft occur, direction of swell and local wind waves likely to differ. 1.) Consider characteristics of vessel in heavy long period swell before departing protection of harbor. 2.) Beware of breaker action near entrance to harbor(s). 3.) Be alert to varying responses by vessels of different length to swell and local waves when conducting along side operations.	b. Result of steepening pressure gradient between thermal low over Turkey and high pressure over the Balkans. 1.) The average duration is about 2 days during early (May-June) and late (September-October) summer and about 4 days during July and August. 2.) Typically at least one 5 day period each year and one 10 day period about every 6 years during July and August.
All Seasons	c. Migratory lows - Begins as southerly (Sirocco) force 7-8 (28-40 kt) becoming westerly force 8-9 (34-47 kt) with waves over 20 ft (6 m) during extreme conditions.	c. High sea and winds at anchorage and throughout Haifa Bay. 1.) Open sea conditions beyond small boat limits. If at sea proceed to nearest protected port at earliest indication of storm threat. 2.) If caught at sea get help and proceed to nearest port. 3.) Stay in port and add mooring lines.	c. The source region of migratory lows varies with season. 1.) Migratory mid latitude lows often intensify over the southern Aegean Sea after crossing Italy, this occurs most often during autumn and winter. 2.) During late autumn and early spring these same migratory lows at times become nearly stationary near Cyprus and intensify again when a strong cold air outbreak occurs over Turkey. 3.) All migratory lows and fronts should be closely monitored for new developments. Upper level short wave troughs and low level cold air outbreaks are features most often associated with redevelopment. 4.) Lows forming over the desert south of the Atlas Mountains of North Africa tend to track northeastward out of the Gulf of Gabes. During spring some of these North African lows track eastward and remain over land until reaching the eastern Mediterranean. These result in extensive dust layers aloft as well as heavy seas and winds off the Israeli coast. The highest winds in these cases tend to be in the northwest sector (over open sea) of the lows.
4. Flight operations. All seasons	a. All high wind and heavy sea conditions.	a. Follow normal heavy weather flight operation procedures.	a. All prior discussions on advance indicators and supporting information apply.
Spring and Summer	b. Reduced slant range visibility resulting from dust aloft and/or salt haze.	b. Dust and salt haze aloft cause sunlight to be scattered. 1.) Slant ranges are reduced significantly more than surface horizontal ranges. 2.) The condition is most severe when viewed toward a low angle sun. 3.) After dark the effect is minimal. Horizontal and slant range visibilities will be nearly equal.	b. Reduction to visibility can be caused by either high winds or stagnate air conditions. 1.) Dust aloft is caused by winds blowing off the desert areas. The North African lows and Sirocco winds are the major cause. 2.) Salt haze is mainly a summer time phenomenon associated with stagnate air masses. The condition tends to prevail throughout the summer at various levels of severity and is wide spread over Mediterranean Sea.

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APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always

present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN- BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period (f = 1/T) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and a given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining

frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \qquad (1.2)$$

Where v is wind speed in knots and T is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \qquad (1.3)$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \qquad (1.4)$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves) period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing

lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) / (hrs)	Sig Wave (H1/3) Period/Height (sec) / (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

[1] Depths throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

[2] For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell their wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

<u>Format:</u> height (feet)/period (seconds)
duration required (hours)

Fetch \ Length \ (n mi)	Wind Speed (kt) 18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

<u>WIND FORECAST OR CONDITION</u>

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

<u>SEA FORECAST OR CONDITION</u>

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water

conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

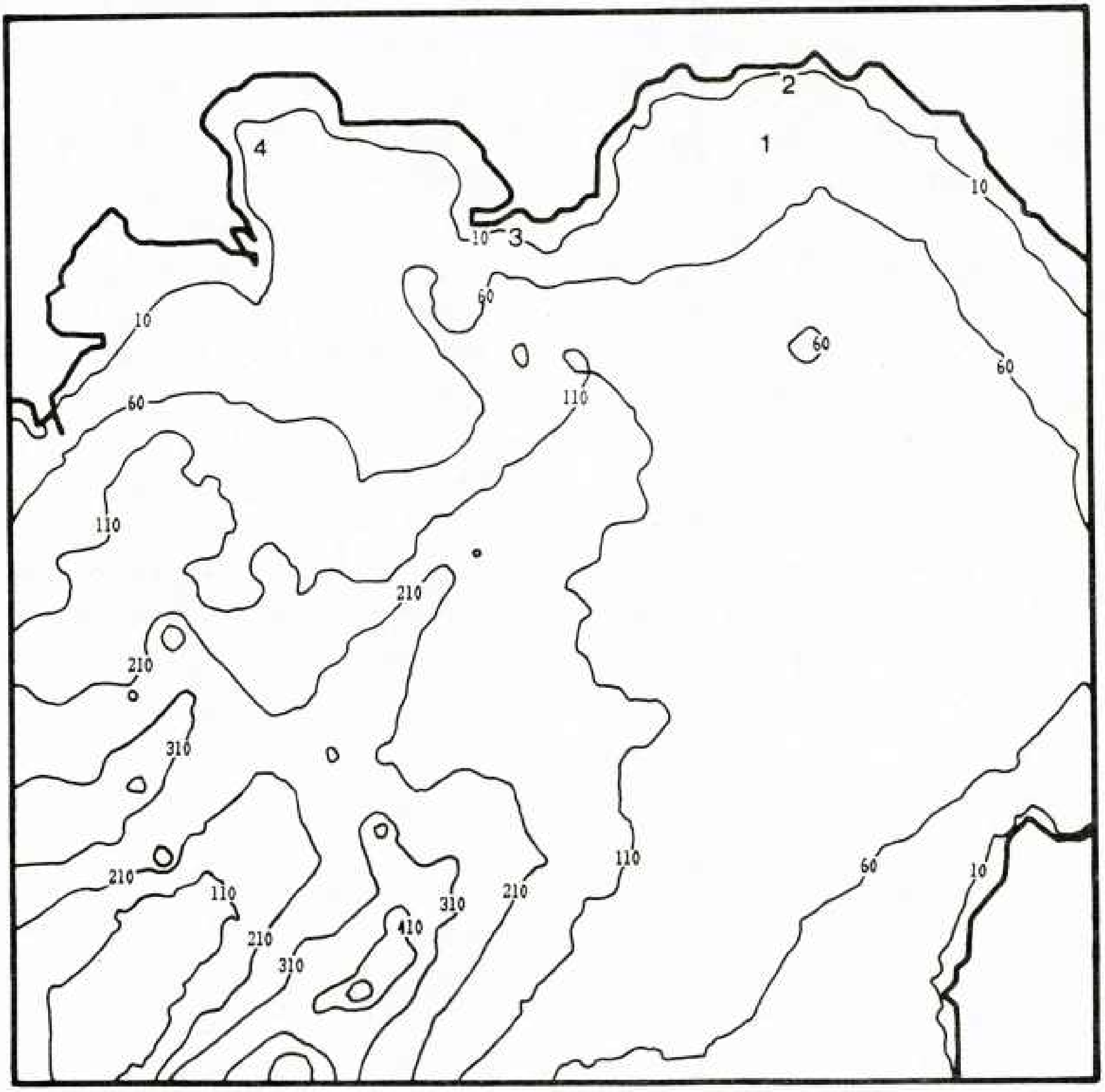

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathoms to 110 fathoms, and at 100 fathom intervals thereafter. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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